California Geological Survey
Fault Evaluation Report FER-264

THE RAYMOND FAULT

in the Mt. Wilson and El Monte Quadrangles
Los Angeles County, California

by
Jerome A. Treiman
April 20, 2017 (revised)

INTRODUCTION

The Raymond Fault is an important element of the southern boundary of the Transverse Range in Southern California. It is the easternmost section of the generally east-west trending Malibu Coast–Santa Monica–Hollywood–Raymond Fault System, a zone of locally transpressive left-lateral faults (Dolan, Sieh and Rockwell, 2000). To the east, near Monrovia, it appears to merge into the central part of the Sierra Madre Fault Zone. To the west the Raymond Fault may step over or merge with the Hollywood Fault (Hernandez, 2016).

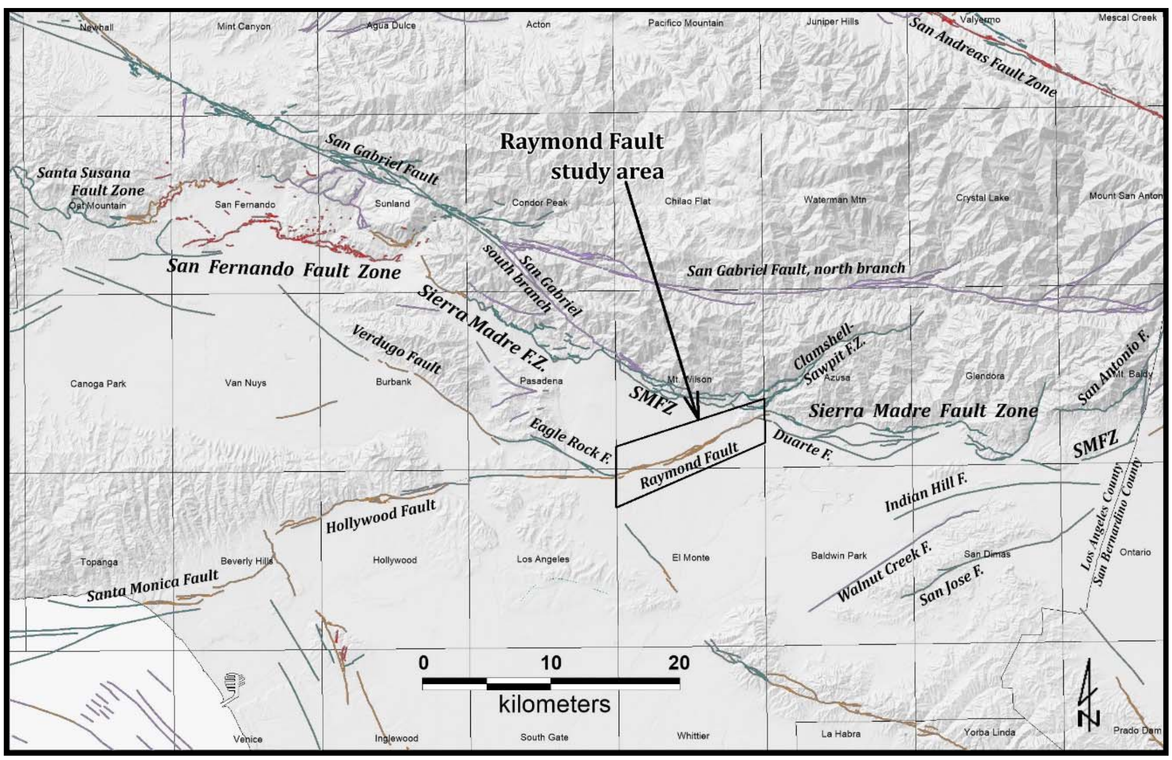

Figure 1 - Location of the Raymond Fault study area and names of principal faults in the region [SMFZ = Sierra Madre Fault Zone]. Faults are color-coded for age of activity: red – historic, orange – Holocene, green – late Quaternary, purple – Quaternary (from California Geological Survey, 2016).

The fault has been called both the Raymond Fault and the Raymond Hill Fault in the past but current usage (e.g., Crook *et al.*, 1987) has settled on the former, for simplicity and based on priority. Bryant (1978) gives a concise summary of the history of mapping and nomenclature.

The Raymond Fault was initially included in an Alquist-Priolo Earthquake Fault Zone (APEFZ) in 1977, based on previous mapping by Buwalda (1940), Proctor (1974b) and unpublished mapping by California Division of Mines and Geology (CDMG, 1977). A small portion on the El Monte Quadrangle was revised in 1991 when that map was being revised for other reasons (Treiman, 1991a, b; CDMG, 1991). The fault, on the Los Angeles Quadrangle is being evaluated by Hernandez (2016). The purpose of this evaluation is to review the evidence for Holocene displacement and locations of surface traces of the Raymond Fault within the Mt. Wilson Quadrangle (Plate 1), utilizing more recent mapping, detailed studies and other available data. We are also reviewing the existing EFZ in the El Monte Quadrangle in light of more recent studies. Fault traces within this area are evaluated relative to the Alquist-Priolo zoning criteria which require that a fault considered for zoning be “sufficiently active” and “well defined” (Bryant and Hart, 2007). Recommendations are made for revision to the existing APEFZ, per those criteria.

Minor changes have been made in this revised report for clarification and to correct non-substantive graphical errors or omissions. No changes have been made to the zoning recommendations.

Previous Mapping

The first map showing the Raymond Fault was by Miller (1928) wherein he showed the fault as a southwest extension of the Sawpit Canyon Fault. Miller remarked on the probable recency of displacement based on the “well preserved scarp in the unconsolidated valley fill”.

The Raymond Fault was named by Eckis (1934) who recognized its role as a groundwater barrier between the Raymond Basin and the greater San Gabriel basin. He also noted the prominent scarp that extended from Monrovia Canyon to Arroyo Seco and delineated the fault westward to the Los Angeles River.

The fault was subsequently studied and mapped in greater detail by Buwalda (1940). Buwalda’s mapping was based partly on observation of numerous small-scale geomorphic and geologic features in addition to the principal scarp observed by Eckis. Geomorphic features included offset streams and deformed surfaces. Buwalda thought the fault was a steeply north-dipping reverse fault. However, he also observed that the sense of offset appeared reversed near Eaton Wash, where the land surface south of the fault appeared higher. He attributed this to a possible pressure ridge rather than as an indication of strike-slip displacement. He also went into considerable detail describing the few outcrop exposures of the fault and near-fault deformation and described water level differences across the fault as observed in wells. His detailed mapping and observations formed a foundation for later workers.

Whereas earlier workers considered the Raymond Fault to have primarily vertical (reverse) displacement, Proctor (1974a) reported observations of evidence of left-lateral creep on the fault (although Crook *et al.*, 1978, later suggested much of this apparent creep might be due to subsidence related to ground water withdrawal). Proctor also prepared a preliminary map of the fault at a scale of 1:24,000 (Proctor, 1974b; fault traces shown on Plate 1). His map compiled many of the observations of Buwalda (1940) along with some additional observations from geotechnical studies and a revised fault interpretation. Proctor’s map, however, needs to be used with caution as some of the features shown are not accurately located.

An Alquist-Priolo Earthquake Fault Zone was established across the Mt. Wilson Quadrangle in 1977 based on the previous work (CDMG, 1977).

Crook *et al.* (1978) mapped faults within the Sierra Madre and Raymond fault zones, with particular attention to faulting of Quaternary deposits. They also identified several subunits of those deposits with inferences as to relative age and the age of faulting. They summarized much of the prior work, but also included new mapping and trench studies in several locations to assess recency of faulting. They believed the fault accommodated a significant amount of left-lateral slip. Their mapping and discussion was formally published nine years later by the USGS (Crook *et al.*, 1987). Their work has been one of the most comprehensive studies of the fault to date and their fault traces are compiled herein on Plate 1. Also shown are their specific observation localities (see also Table 1).

Treiman (1991b) made a cursory revision of the 1977 APEFZ for the Raymond Fault on the El Monte quadrangle. This work primarily brought the EFZ mapping into conformance with the mapping of Crook *et al.* (1987), with additions from aerial photo interpretation.

Weaver and Dolan (2000) presented an updated discussion of the geomorphology of the fault zone, accompanied by new paleoseismic investigations which demonstrated evidence of Holocene surface rupture along this fault. They divided the fault into five sections based on fault character and geomorphology; four of these sections fall on the Mt. Wilson and El Monte quadrangles. Their analysis also supported the interpretation that displacement on the fault is primarily left-lateral. Their revised fault traces are also shown on Plate 1.

--ooOoo--

Site-Specific Geotechnical and Fault Studies

Since the original APEFZ was established in 1977 there have been a number of fault studies made for development projects along the fault, as well as research investigations. Studies that are particularly significant to the current analysis are summarized here, from west to east. These, as well as other studies, are also indicated on Plate 1.

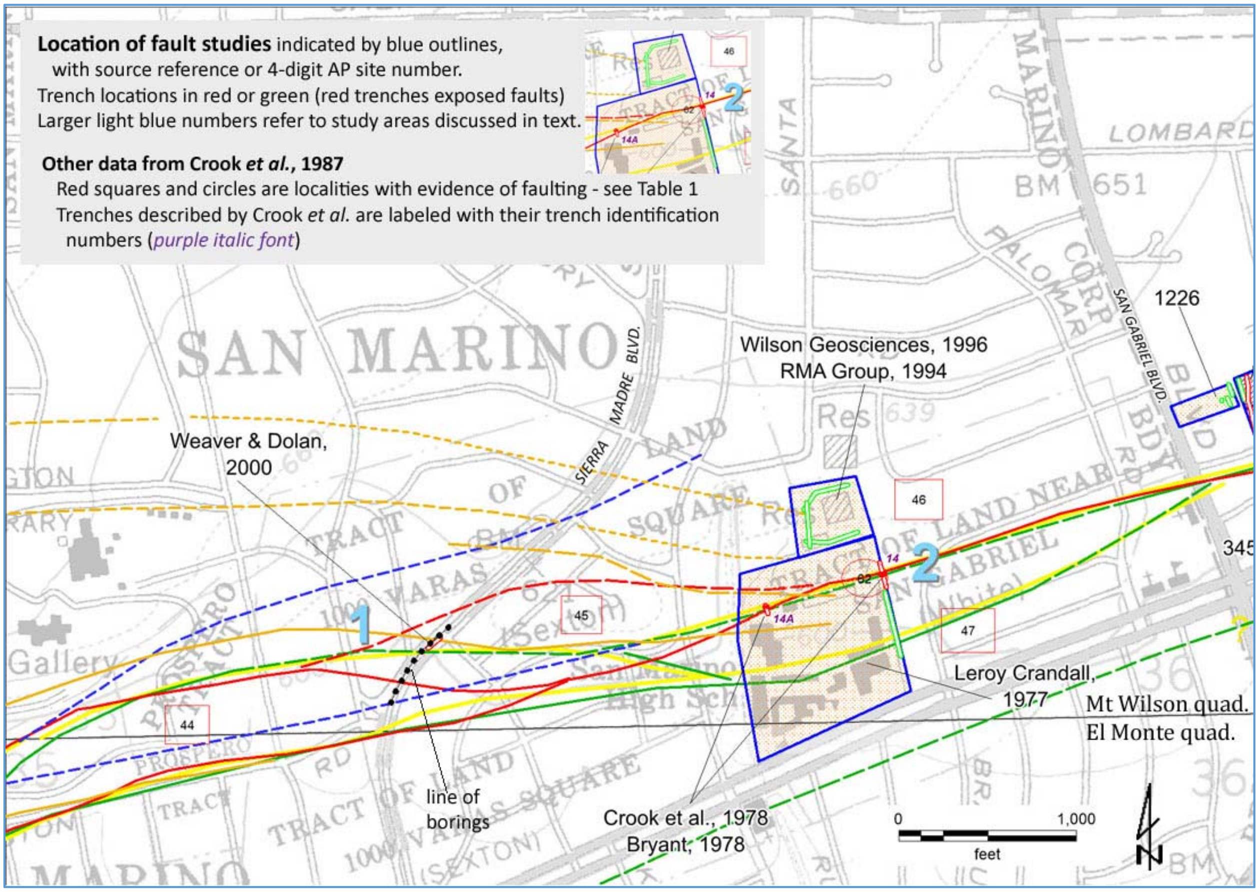

Figure 2 – Previous mapping and investigations in the San Marino area; study areas 1 & 2. Blue fault lines are from Buwalda (1940); red fault lines are from Crook *et al.* (1987); green fault lines are from Proctor (1974b); yellow fault lines are from CDMG (1977 and 1991 APEFZ maps); gold fault lines are from Weaver and Dolan (2000).

1. Sierra Madre Boulevard – Weaver and Dolan (2000) made a borehole transect and excavated a paleoseismic trench across the fault within the median of Sierra Madre Blvd. The borehole transect constrained significant faulting to the northeast part of their study site. Their trench found a zone of faulting with evidence of at least five surface rupture events that occurred between 31 to 45-thousand years ago. Evidence of more recent rupture was lost when the site was graded in the early 1900s and again in 1951.

2. San Marino High School and vicinity – Crook *et al.* (1987) summarized the findings at two trenches excavated at San Marino High School by Leroy Crandall (1977). The trenches encountered two strands of the Raymond Fault and documented multiple episodes of

displacement. They also provided evidence that primary displacement is strike-slip. Based on radiocarbon dating of a faulted peaty silt horizon, the last event recognized in these exposures occurred between ~3575 ybp and ~1630 ybp. Fault location was also constrained by a third trench to the south that did not find evidence of faulting. Trenches by RMA Group (1994) and Wilson Geoscience (1996) around the reservoir to the north of the campus also found no evidence of faulting.

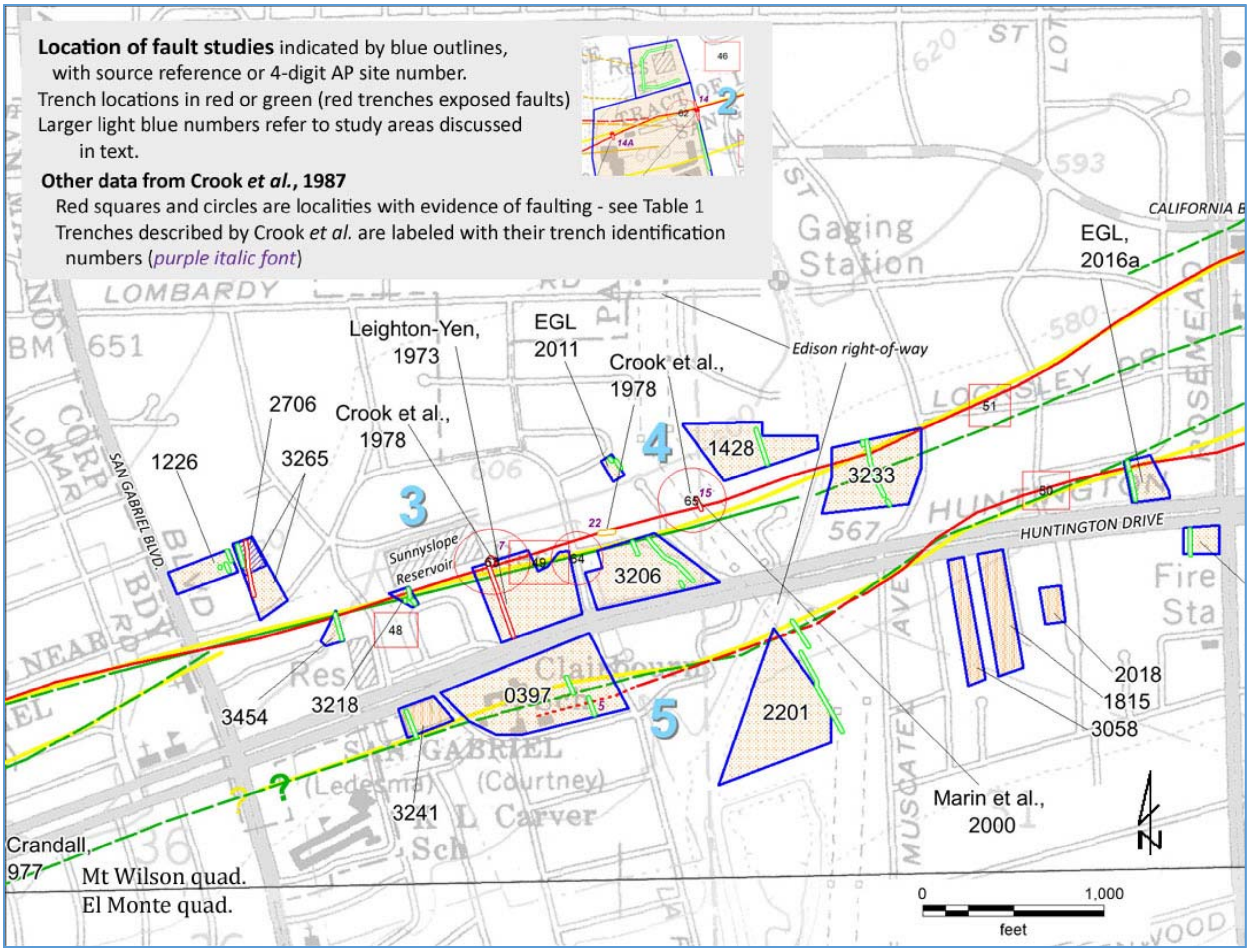

Figure 3 – Previous mapping and investigations between San Gabriel Blvd. and Rosemead Blvd.; study areas 3, 4 & 5. Red fault lines are from Crook *et al.* (1987); green fault lines are from Proctor (1974b); yellow fault lines are from CDMG (1977 APEFZ map).

3. Sunnyslope Reservoir and vicinity –Two trenches at the southeast corner of the reservoir and southward exposed faulted Holocene deposits (Leighton-Yen, 1973; also referenced by Crook *et al.*., 1987; Payne and Wilson, 1973 & 1974; Proctor, 1974b). Crook *et al.* (1978) excavated a research trench adjacent to one of the 1973 trenches; the trench exposed faulting that offsets presumed Holocene marsh deposits. Trenches to the south (AP-3218) and southwest (AP-3454) found no faulting. A trench to the west, north of the

main trace, found subsidiary faults that displaced alluvium that could be Holocene (AP-3265).

4. Edison right-of-way and vicinity – Trenches by Crook *et al.* (1978) and Marin *et al.* (2000) located the main trace of the fault within the powerline right-of-way. Marin *et al.* (2000) identified a zone of faulting approximately 10 m wide and interpreted a minimum left-lateral slip rate of 1.5 mm/yr. Other trenching studies in the area, north and south of the principal fault strand, did not expose any faults (AP-1428; AP-3206; AP-3233; EGL, 2011).

5. Southern trace, east of San Gabriel Blvd. – Fault investigations south of Huntington Drive found no evidence for southern trace as mapped by Crook *et al.* (1987) or as plotted on CDMG (1977). [AP-0397; AP-2201; AP-3241]. Another investigation near Rosemead Blvd. also did not find evidence of faulting (EGL, 2016a).

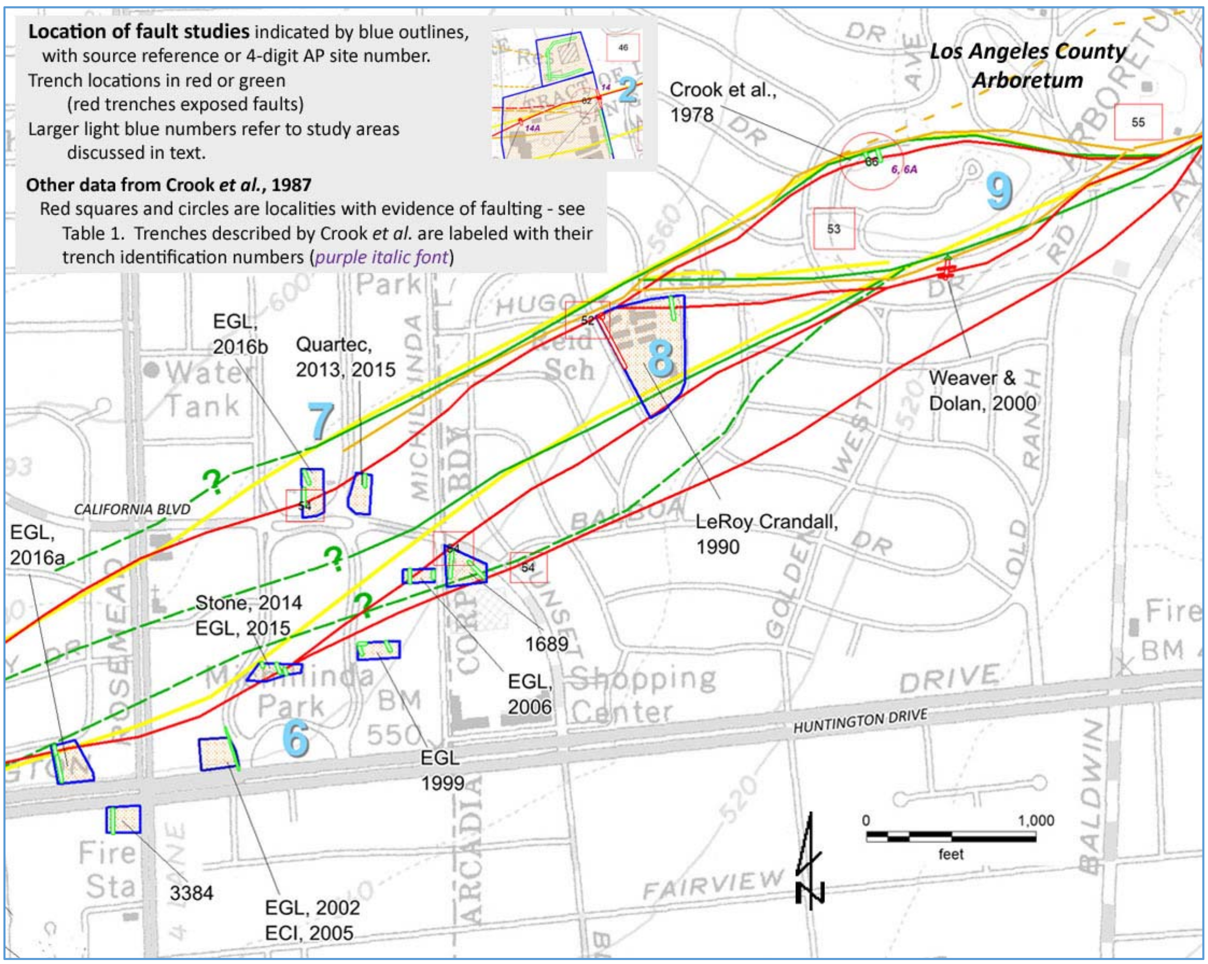

Figure 4 – Previous mapping and investigations between Rosemead Blvd. and Baldwin Ave.; study areas 6, 7, 8 & 9. Red fault lines are from Crook *et al.* (1987); green fault lines are from Proctor (1974b); yellow fault lines are from CDMG (1977 APEFZ map); gold fault lines are from Weaver and Dolan (2000).

6. Southern trace, Rosemead Blvd. to Michillinda Ave. – several studies along this reach of the fault found no evidence for faulting. [multiple studies – see Figure 4].

7. Main strand, California St. / Michillinda Ave. – A fault trench just north of California St., west of Michillinda Ave., found warped terrace deposits that suggest the Raymond fault is likely just south of that investigation site (EGL, 2016b). A study across the street to the east (Quartec, 2013, 2015) did not find a fault either, and depicted the fault lying to the north and west of that site. The fault is inferred to pass diagonally between these two sites.

8. Hugo Reid Elementary School – Trenches by LeRoy Crandall (1990) located a steeply southeast-dipping fault trace across the northwest corner of the campus. Faulted sediments are younger than 3550 +/- 155 yrs bp. An eastern splay, as depicted by Crook *et al.* (1987), was also investigated by a trench on the eastern part of the campus and was not found within the extent of the trench.

9. Los Angeles County Arboretum – Two trenches by Crook *et al.* (1978) on the north side of an inferred pressure ridge did not encounter faulting but they speculated that the fault may lie north of their trenches. Weaver and Dolan (2000) excavated a trench on the south side of the pressure ridge that exposed two zones of faulting and they inferred a third fault to the south; displacement was interpreted to have occurred since 8050 B.C.

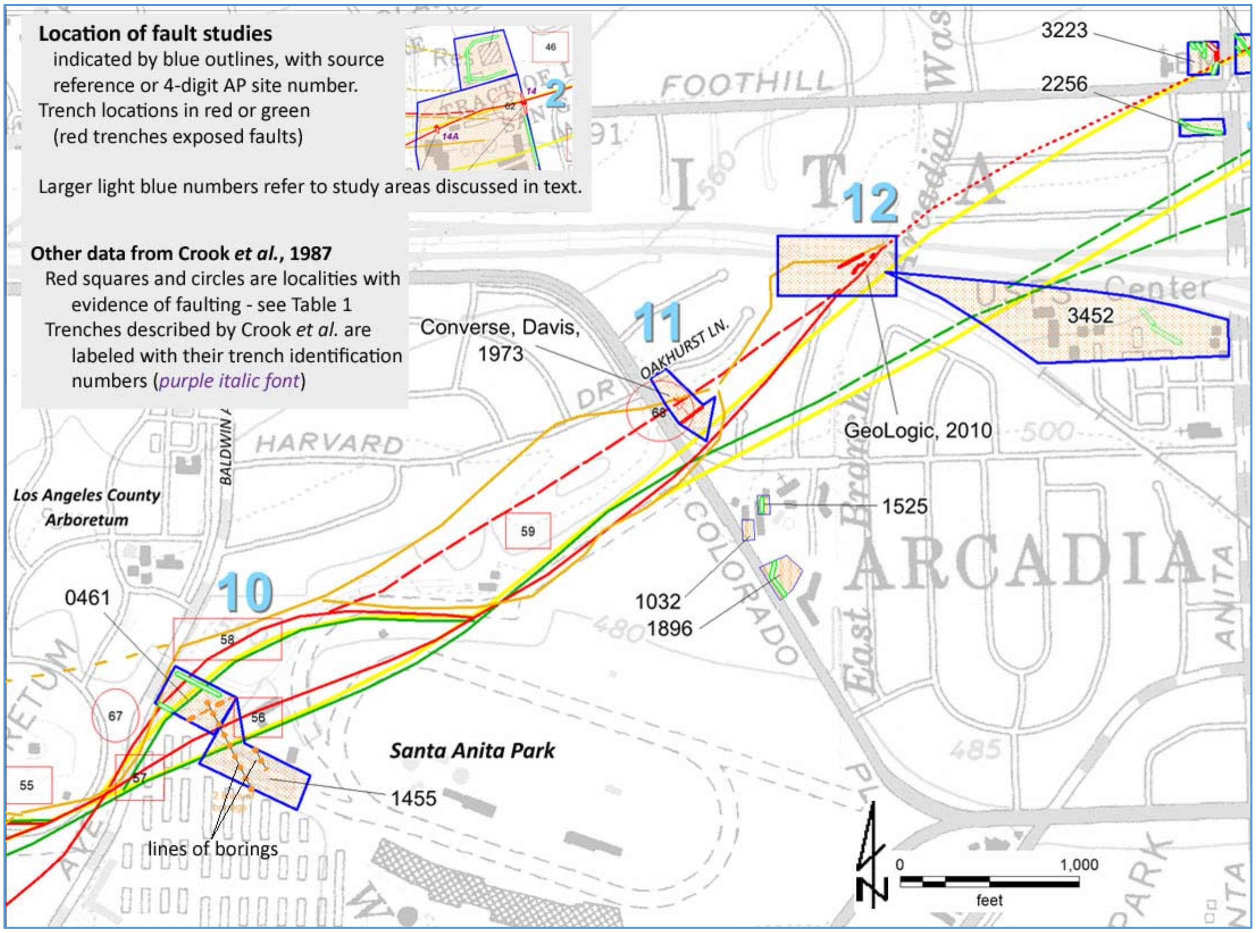

Figure 5 – Previous mapping and investigations between Baldwin Ave. and Santa Anita Ave.; study areas 10, 11 & 12. Red fault lines are from Crook *et al.* (1987); green fault lines are from Proctor (1974b); yellow fault lines are from CDMG (1977 APEFZ map); gold fault lines are from Weaver and Dolan (2000).

10. Baldwin Avenue/ Santa Anita Park – Borings and trenches [AP-0461; AP-1455] did not find either fault trace as previously mapped (CDMG, 1977; Crook *et al.*, 1987). However, AP-1455 did find that stratigraphic discontinuities and offsets were suggested by data from borings for that study and previous studies by the consultant. Based on these data they interpreted a Holocene fault located in between the previously mapped fault traces. Grading to the west, for Baldwin Avenue, exposed young alluvium faulted against marsh deposits (Payne and Wilson, 1973; Proctor, 1974b; Crook *et al.*, 1987, circled loc.67)

11. Oakhurst Lane – A fault study by Converse, Davis and Associates (1973) exposed at least one trace of the Raymond Fault and found evidence of another likely fault trace. The observed fault was described as offsetting "young" stratified alluvial deposits and the overlying colluvium. A structural setback was recommended and implemented.

12. Metro Gold Line, Foothill Extension – A detailed study for construction of a light rail overpass found evidence of several strands of the fault. One, probably older, normal fault was exposed in a trench and three other strands were interpreted based on possible offset

of the base of a Holocene colluvial unit as interpreted from borings. A continuous trace was not well-defined. (GeoLogic, 2010a, 2010b).

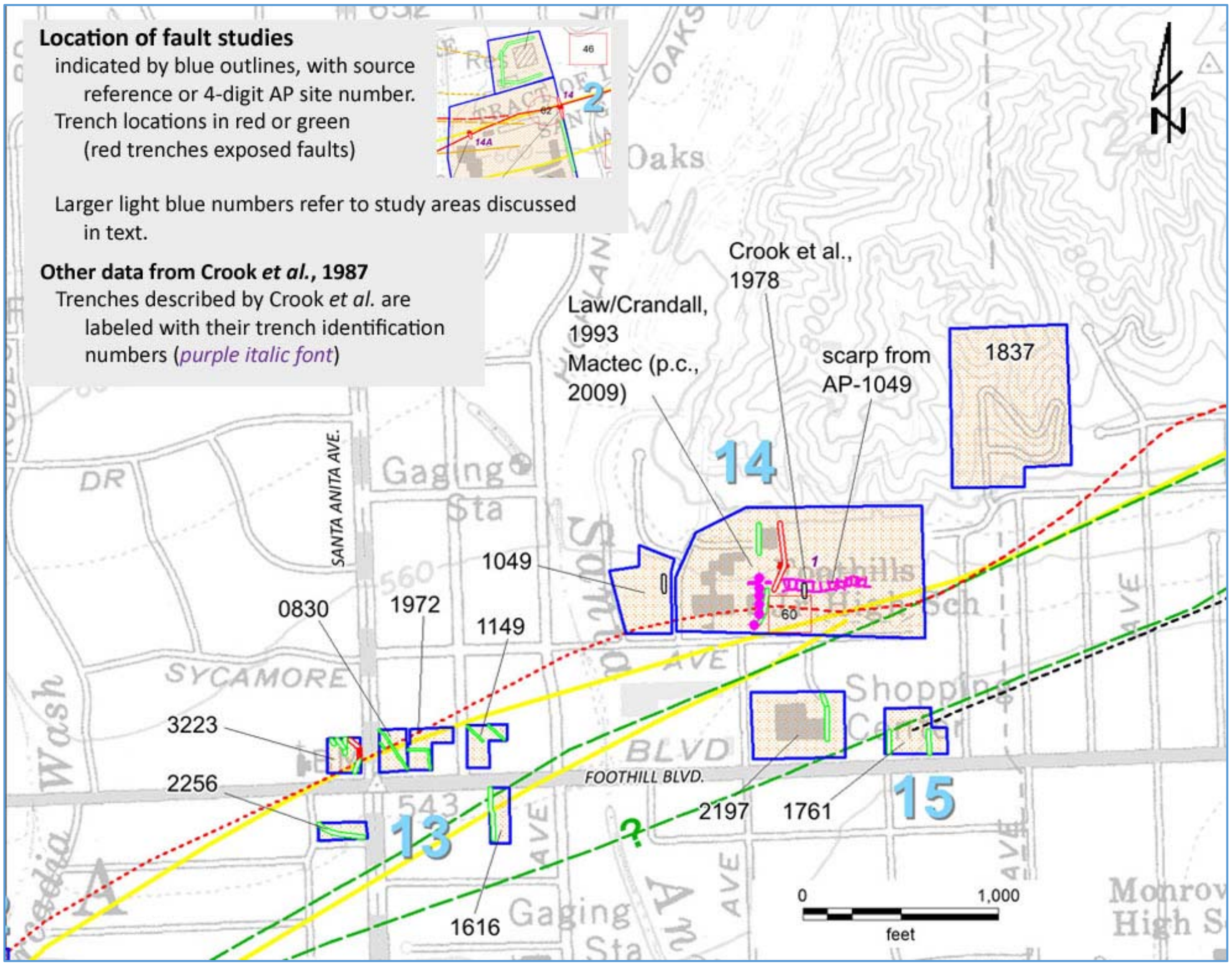

Figure 6 – Previous mapping and investigations near Santa Anita Wash; study areas 13, 14 & 15. Black fault lines are from Morton (1973); red fault lines are from Crook *et al.* (1987); green fault lines are from Proctor (1974b); yellow fault lines are from CDMG (1977 APEFZ map).

13. Santa Anita Ave. and Foothill Blvd. – An investigation on the northwest corner of this intersection found evidence of a zone of faulting, corresponding to the previously mapped northern trace, within two trenches [AP-3223]. An investigation on the northeast corner [AP-0830] explored only young, unconsolidated sediments and did not present useful trench logs and, as such, was inadequate to disprove the presence of a fault. The previously mapped southern strand was trenched at another site to the southeast (AP-1616) and no evidence was found for that fault strand. An air photo lineament, still further south, and west of Santa Anita Ave., was not found in trenching (AP-3452).

14. Foothills Junior High School – Interpretation of an early (1960) site topographic map by Crook (included in AP-1049, plate 3) suggested a possible fault scarp across the school

site (also visible in 1928 and 1938 aerial photographs), but a trench to explore this feature did not expose a fault (Crook *et al*., 1978, trench 1). A seismic survey and trench (AP-1049) on the site just to the west also did not find evidence of faulting. A trenching investigation in 1993 (Law/Crandall, 1993) found significant shearing within a very limited exposure of Cretaceous diorite but no evidence of faulting in the Quaternary alluvium exposed in the rest of their trenches. The poorly to moderately consolidated alluvium was not dated. A subsequent subsurface investigation in 2007 or 2008, utilizing borings, found a large (>10 m) apparent offset in the top of the crystalline bedrock that is likely attributable to faulting (R. Munro, MACTEC, personal communication, 2009; Pasadena Star News, 01/23/3008).

15. The Raymond Fault was shown as a concealed trace approximately 250-330 m south of the mountain front by Morton (1973). This feature has only been explored by one study (AP-1761) which did not find any evidence of faulting.

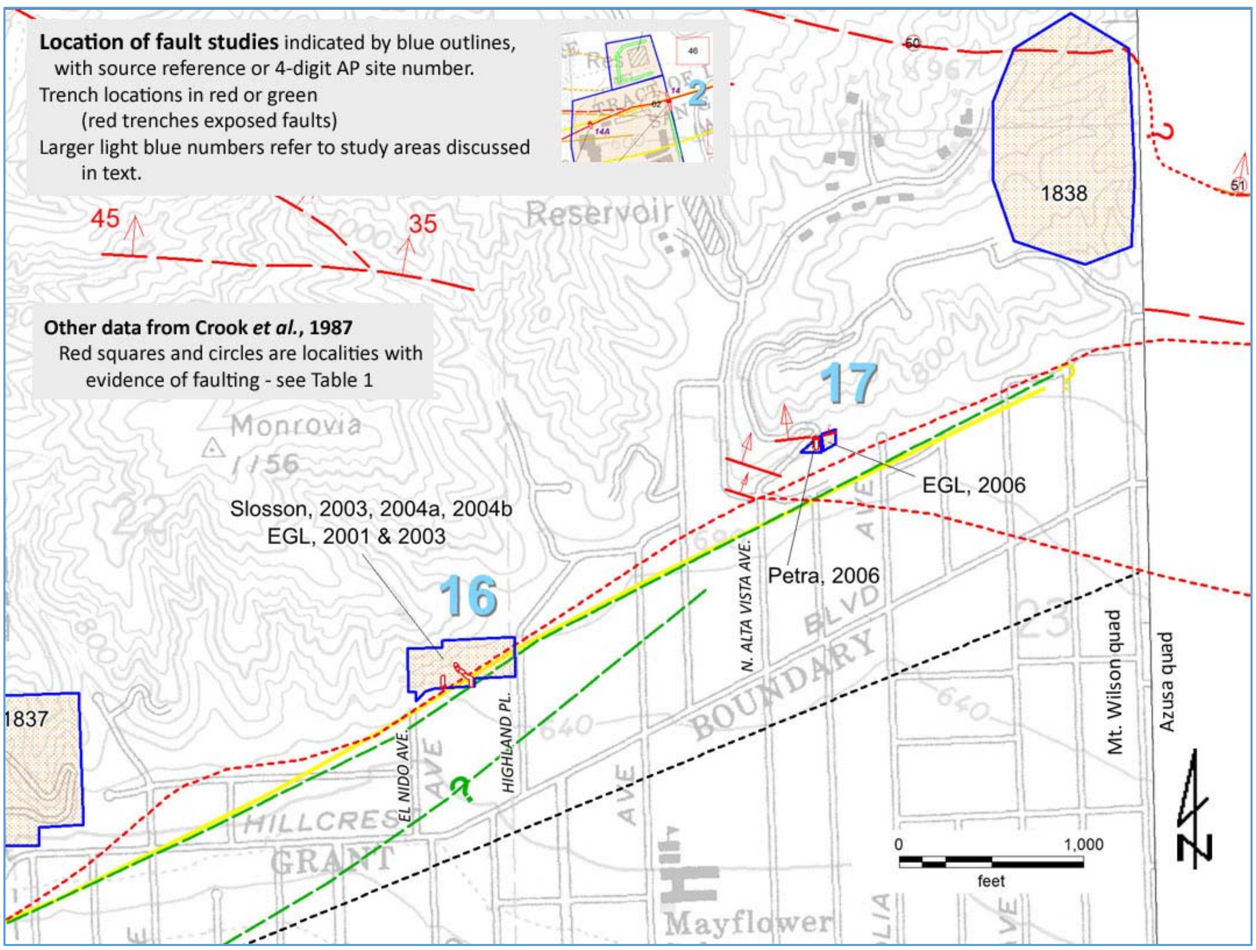

Figure 7 – Previous mapping and investigations in the Monrovia area; study areas 16 & 17. Black fault line is from Morton (1973); red fault lines are from Crook *et al.* (1987); green fault lines are from Proctor (1974b); yellow fault lines are from CDMG (1977 APEFZ map).

16. El Nido Ave./Highland Pl. - A fault study by Hawkins in 1991 (cited by Slosson and Associates, 2003) found one trace of the Raymond Fault at the break in slope. A trench on the adjacent property to the west found evidence of another fault trace, south of the slope (EGL, 2001). Subsequent investigations on that property found additional evidence of a fault trace along or near the base of slope (EGL, 2003; Slosson and Associates, 2004a,b).

17. North Alta Vista Ave. – Two residential site studies along Alta Vista Avenue found secondary faults in trenches (Petra, 2006; Ray Yang, personal communication, EGL, 2006b). The observed faults were within the crystalline bedrock and Pleistocene Saugus Formation. Crook *et al.* (1978) also described a nearby exposure of diorite faulted over Saugus Formation along Alta Vista Ave. The principal trace of the Raymond Fault is inferred to lie south of the investigation sites.

<u>Aerial Photo/Geomorphic Interpretation/Field Observations</u>

A thorough re-interpretation of vintage aerial photographs and topographic maps (see references), including digital elevation data based on lidar (LARIAC, 2006) has been conducted for this review. These observations and interpretations are included on Plate 2, utilizing the 1924-25 topographic survey as a base map (USGS, 1928a, b). Geomorphic observations of Buwalda (1940), many of which are no longer visible in the field, are also noted on this plate. Earlier, unpublished aerial photo interpretation by R.L. Hill (CGS internal files and notes, undated, ca.1970s) was also considered. To aid discussion the fault is described as five sections, numbered from west to east. The section boundaries match those suggested by Weaver and Dolan (2000), except that we have added one more division and reversed their order.

No surface exposures are known of the Raymond Fault within the Mt. Wilson quadrangle, although Crook *et al.* (1987) described a singular exposure to the southwest, at Alhambra Wash. A field reconnaissance (9/21/16) for this study was only able to verify some of the more general geomorphic features, but most detail has been obscured by development. Some of the fault-study trenches cited above were also observed at the invitation of consultants.

Specific observations and interpretations relative to the current evaluation are summarized below.

A. Kewen Canyon to Rubio Wash ((Weaver and Dolan, 2000, Zone IV)

The principal fault trace is defined by a very prominent south-facing scarp from west of Kewen Canyon to an unnamed canyon west of the Huntington Library and Botanic Gardens (“the Huntington”; also labeled Huntington Estate on 1928 topographic map). In this area the fault splits, with a northern trace becoming more prominent and the southern trace diminishing eastward. The northern trace initially veers northeast as it cuts across the end of a ridge with a notable scarp and then extends across the southern part of the Huntington. This northern trace, as interpreted by Weaver and Dolan (2000) and supported by aerial photo interpretation and lidar data, appears to lie up to 80 meters north of the trace shown on the current APEFZ map. Based on our interpretation of the vintage imagery and recent lidar data the fault appears to make a small left step just east of the Huntington and continues across Sierra Madre Blvd. The southern fault splay, initially marked by a scarp, is not as clearly visible in the landscape to the east but was inferred to bound a closed depression that once lay in the southeast portion of the Huntington (visible in vintage aerial imagery and also depicted on the 1928 topographic map). This feature may be related to back-tilting of the fan surface, as noted by Buwalda, or may lie within a fault-bounded structural depression.

Within the El Monte quadrangle, to the southwest, Lacy Park is on the site of an old sag pond, Wilson Lake. This feature appears to be bounded on the south by a probable fault which had been previously mapped and zoned. Lineaments in vintage aerial imagery and a distinct north-facing slope break extend this feature approximately 160 m further west than shown on the previous EFZ map (CDMG, 1991), but it cannot be identified extending further west into the Los Angeles quadrangle (Hernandez, 2016).

Between Sierra Madre Blvd. and Rubio Wash there is an east-west elongate ridge that is probably a pressure ridge at a restraining bend in the fault. A fault has been suggested, in different forms, on the north side of this ridge by Buwalda (1940), Crook *et al.* (1987) and Weaver and Dolan (2000). However, profiles from lidar data do not indicate any consistent elevation change across the inferred fault and there is little other evidence for its presence here or as it might project across Rubio Wash.

In addition to geomorphic features identified along the trace of the fault, evidence of surface deformation north of the fault has also been noted. A broad (~1 km wide) upwarp, underlying the Huntington, appears to have a linear northern boundary, roughly followed by Arden Rd. and Orlando Rd., which may indicate another fault trace. Several drainages are incised across this warp, beginning at the northern lineament. Whether this feature is related to a (presumed) south-dipping secondary fault or merely folding of the ground adjacent to the fault cannot be determined by this study.

Two additional faults have been interpreted across this upwarp based on geomorphic evidence. One fault, suggested by Buwalda (1940, p.48) at the southwest corner of the Mt. Wilson Quadrangle, was mapped by Crook *et al.* (1987) and also by Weaver and Dolan (2000). This inferred fault lies at the base of a 15-meter step in the terrace surface approximately 400-600 m north of the main scarp. Buwalda (1940) also suggested, as an alternate interpretation to fault displacement, that this step might be related to erosional retreat of the terrace edge after a previous episode of faulting. Topographic analysis for this study indicates that this possible scarp does not extend westward across Kewen Canyon and also that the intermediate surface, between the step and well-defined scarp to the south, is also lower than the adjacent terrace surface west of Kewen Canyon. The intermediate surface also is more irregular and dissected appearing than the higher surfaces to the north and west and looks very much like an inset terrace. Furthermore, streams that cross the inferred fault show inconsistent deflection, if any, arguing against strike-slip displacement. These factors favor the erosional interpretation suggested by Buwalda (1940).

Another possible fault, a little further north, was interpreted by Weaver and Dolan (2000) based on a few aligned stream deflections (see Figure 8).

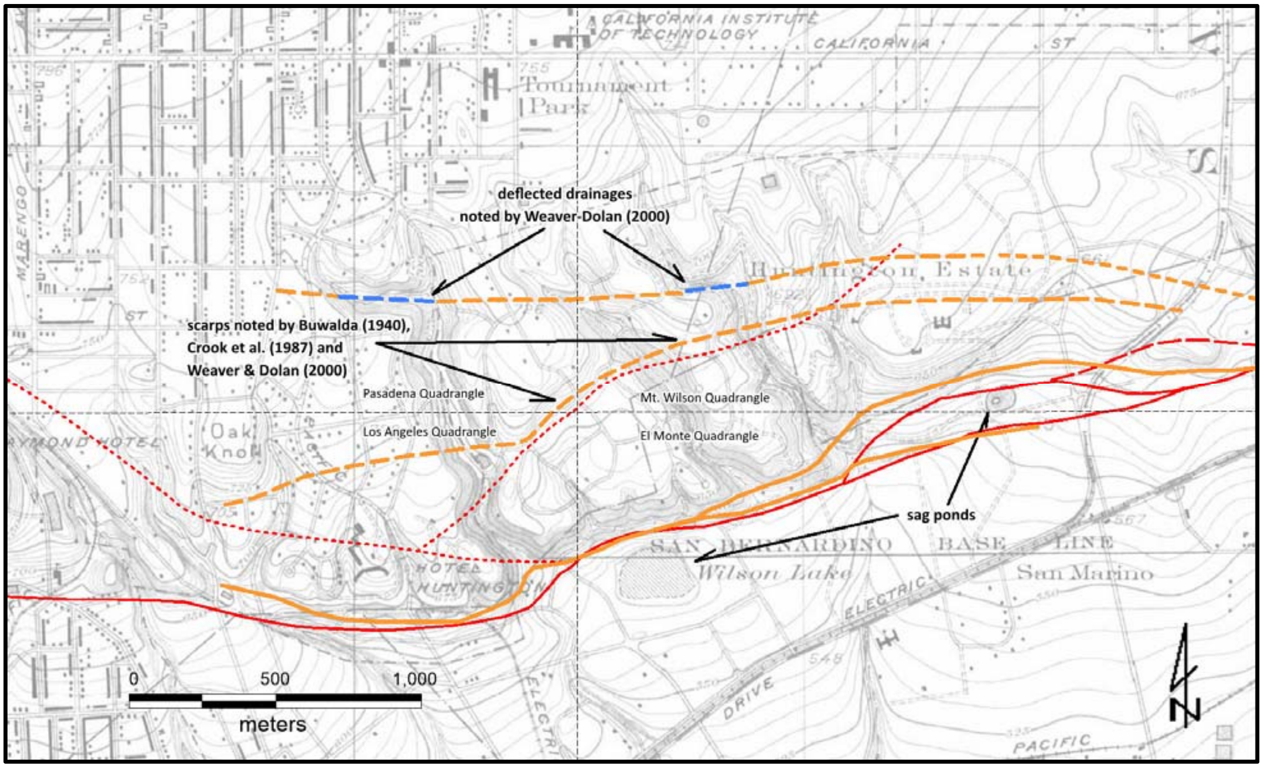

Figure 8 – Detail of San Marino area, showing interpreted features from Buwalda (1940), Crook *et al.* (1987; red lines) and Weaver and Dolan (2000; orange lines). The two later interpretations were very close to that of Buwalda, for the main fault trace. Base map is part of 1928 Altadena 6' quadrangle map.

B. Rubio Wash to Eaton Wash (Weaver and Dolan, 2000, western part of Zone III)

The fault scarp is not consistently well defined in this area. A general landscape descent to the south approaching the fault is evident in the western portion of the area, but with a weak north-facing scarp, or at least a low pressure ridge, locally interpreted along the fault, such as just west of San Gabriel Blvd. East of San Gabriel Blvd. the fault scarp appears to veer north of its trend before the fault steps back to the south. A possible northern fault strand is indicated by a left-lateral stream deflection that is accompanied by what appear to be very subdued fault facets in the adjacent slope (1928 imagery, frame K338).

Some north-facing scarps appear to characterize the eastern section, approaching Eaton Wash, and some minor drainages show left-lateral offset or deflection along the main trace

A southern splay on the current APEFZ map, west of San Gabriel Blvd. (CDMG, 1977) is suggested as a complementary fault to the main trace, and corresponds with a possible scarp in older imagery. Another splay, east of San Gabriel Blvd. may deflect a tributary stream to Eaton Wash, but is otherwise not well expressed.

C. Eaton Wash to Altura Road (Weaver and Dolan, 2000, eastern part of Zone III)

From Eaton Wash to the Los Angeles Arboretum the fault is marked by a general uplift on the north, but also by north-tilted surfaces adjacent to the fault (Buwalda, 1940). A linear depression identified north of the fault just east of Eaton Wash was also noted by Buwalda as an artificially enhanced depression related to uplift south of the fault. The fault was further indicated by a series of subtle south- and north-facing scarps. One of these north-facing scarps, nearly 1 m high, is still visible in an alleyway just west of Michillinda Ave. Buwalda observed several older channels incised across the fault-related uplift, several of which are evident in the 1926 topographic map at the eastern end of this section.

A parallel fault strand and splay, mapped to the south by Crook *et al.* (1978), is not geomorphically evident. Crook *et al.* (1978) cited a scarp and vegetation lineament in 1929 aerial imagery. We were not able to verify the scarp in the same imagery, although a weak alignment of trees could be seen. Crook *et al.* may also have been influenced by the map of Proctor (1974b) which mis-located some of Buwalda's tilted surfaces.

D. Altura Road to Santa Anita Wash (Weaver and Dolan, 2000, Zone II)

The fault becomes much more prominent through the Los Angeles County Arboretum where it bifurcates and bounds a prominent pressure ridge that rises up above the general fan surface. Just east of the pressure ridge is a prominent historic spring-fed sag pond that was also noted by Buwalda (1940; also Crook *et al.*, 1987). Topographic and tonal features suggest a secondary parallel fault trace just to the north.

Immediately east of the Arboretum, into the Santa Anita Park area, the fault zone has discontinuous expression. A linear slope within an arcuate topographic embayment may be influenced by a subsidiary northern fault splay. Also, the drainage (Arcadia Wash) from the sag pond within the Arboretum takes a pronounced linear northeastern detour before draining south again. In the northeastern part of the Park, the fault is marked by another prominent pressure ridge and south-facing scarp. The East Branch of the Arcadia Wash, just east of Santa Anita Park, is notably incised into the higher terrain north of the fault. Between that drainage and Santa Anita Wash the Raymond Fault has no detectable expression and is evidently concealed by young fan deposits. A southern fault strand, as mapped by CDMG (1977) and suggested by Proctor (1974b) (see Figure 5), also has no expression.

E. Santa Anita Wash to Sawpit Canyon (Weaver and Dolan, 2000, Zone I)

East of Santa Anita Wash the fault appears to control the linear southern boundary of a prominent crystalline uplift, termed the Monrovia outlier by Crook *et al.* (1987). Erosional debris from this uplifted terrain has buried much of the fault, but a possibly fault-related scarp was visible at the site of Foothills Middle School in Arcadia, prior to more recent grading (unpublished map by Crook *et al.*, included in AP-1049). Faceted spurs just to the north of the school mark another likely fault trace at an inferred stepover in the fault. Additional mountain-front facets to the east indicate that the fault is close to the linear base of the uplift. Analysis of lidar data also suggests some subparallel splays which can be interpreted across a few of the younger fan surfaces. One of these is suggested by a break in slope crossing El Nido Ave., north of Crescent Dr. Other subtle scarps may be interpreted across young fans that emanate from the mountain front near Heather Heights Ct. and Highland Pl. Approaching Sawpit Canyon and the eastern map boundary, the fault appears to have some clearer scarps at the mountain front that merge into those identified on the adjacent Azusa Quadrangle (Treiman, 2013 & 2014).

Possible fault strands farther south of the mountain front, as delineated by Morton (1973) and Proctor (1974b), have no convincing surface expression. Proctor (1974b) suggested that a section of Santa Anita Wash may have been offset 2800 feet to the east, and abandoned. Although this abandoned reach of the wash appears to terminate headward at the inferred southern fault trace, it is just as likely that its northern extent has been buried by the coalescing alluvial fans forming below a steep, dissected section of the Monrovia outlier.

Seismicity

A M 5.0 earthquake on December 3, 1988 in the Pasadena area has been attributed to the Raymond Fault (Jones *et al.*, 1990). The earthquake and its aftershocks define a plane that strikes east-northeast and projects to the surface trace of the Raymond Fault. Furthermore, the focal mechanism supports left-lateral strike-slip displacement. Relocated earthquake epicenters (1981-2011) are shown on Figure 9.

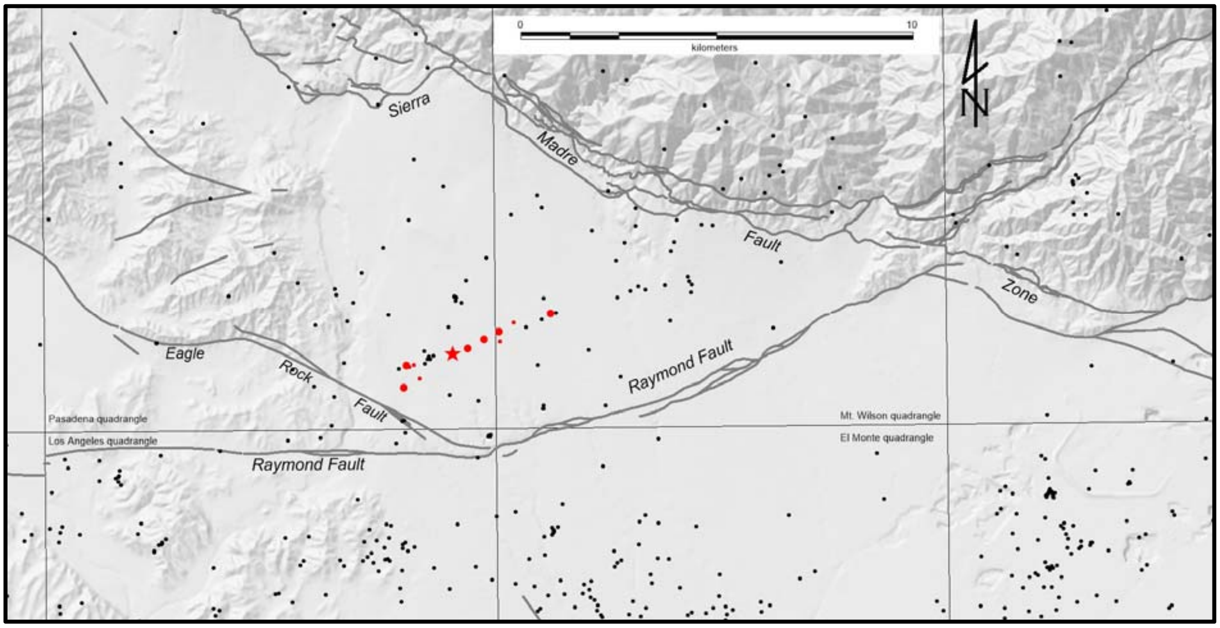

Figure 9 – Relocated epicenters for earthquakes from 1981-2011 (all magnitudes) are from Hauksson, Yang and Shearer (2012). The December 3, 1988 M5.0 earthquake (star) and one week of aftershocks are indicated in red. Faults are from CGS (2016).

Discussion and Conclusions

The currently zoned traces of the Raymond Fault were based on early mapping (Buwalda, 1940; Proctor, 1974b). The fault trace locations can now be improved based on subsequent trench investigations and careful geomorphic interpretation based on historic topographic maps, lidar data and aerial imagery.

A. Kewen Canyon to Rubio Wash

The previously mapped fault pattern (CDMG, 1977; Crook *et al.*, 1987; Weaver and Dolan, 2000) appears to be generally correct, but new interpretation of aerial imagery and lidar data warrant some modifications.

The split of the fault into a northern and southern strand has been placed in different locations by Crook *et al.* (1987) and by Weaver and Dolan (2000). We suggest moving this junction, based on a fairly prominent bench and apparent scarp that lies between these two interpretations. Our northern strand continues eastward from this point, very much as interpreted by Weaver and Dolan (2000), but we think it probably veers closer to the north margin of an old pond and then makes a left step to the trace that was confirmed by Weaver and Dolan's trench at Sierra Madre Blvd. We slightly modify the southern trace, the main trace of Crook *et al.*, to better fit the topography. Based on the strength of geomorphic expression, principally fault scarps and local depressed areas, it might be inferred that there is actually a series of two left steps between the southern strand at the western margin of the quadrangle, and the apparent main strand as it crosses Sierra Madre Blvd. The two principal strands appear to rejoin east of Sierra Madre Blvd., approaching Rubio Wash, based on their trends and the identification of just a single trace east of the wash.

A more northern fault splay was also mapped by Crook *et al.* (1987), and a similar trace was suggested by Weaver and Dolan (2000), to provide a northern boundary to the small pressure ridge just west of Rubio Wash. We do not see any convincing evidence for this fault and it does not appear to have affected Rubio Wash, as depicted in the older topographic map or in the vintage aerial imagery. Topographic profiles across the feature also were not convincing.

The inferred fault, south of Wilson Lake/Lacy Park, can be extended further west based on subtle tonal lineaments and topographic expression.

Suggested faults north of the Raymond Fault

A broad surface warp, north of the fault in the western part of the study area (see Plate II) has a somewhat well-defined northern margin that might be fault controlled and exhibits enhanced incision of the drainages that cross it. The warp is almost certainly related to stresses adjacent to the fault but does not necessarily require the presence of any active surface faults north of the primary Raymond Fault traces.

A possible fault at the southwest corner of the Mt. Wilson quadrangle, suggested by Buwalda (1940) and subsequently mapped by others, lacks geomorphic continuity and is more likely an erosional scarp, as alternatively proposed by Buwalda (1940).

An east-west trending fault, suggested by Weaver and Dolan (2000) to control some minor drainages, is possible but the drainage deflections could also be the result of the drainages being defeated by surface warping. There is also no evidence that the inferred fault has had recent activity.

B. Rubio Wash to Eaton Wash

Crook *et al.* (1987) mapped one principal fault trace in this reach, which has generally been corroborated by subsequent investigations. Significant studies include those at San Marino High School (2), Sunnyslope Reservoir area (3) and near Eaton Wash (4). However, geomorphic features in the central part of this fault section suggest that there may be some complexity to the trace, and we infer a short parallel strand to the north as well as a minor extensional stepover along the fault in the vicinity of Sunnyslope Reservoir. The latter is based on an irregular south-facing scarp or slope that veers north of the main fault trend, and several trench investigations that verify the main trace as mapped southeast and east of Sunnyslope Reservoir.

The more northern fault strand is interpreted based on stream offset and possible scarp facets along Sunnyslope Blvd., as interpreted from vintage aerial imagery. The activity of this splay is suggested by proximity to the principal active strand as well as the geomorphic expression. That fault-related strain and complexity extend north of the main trace in this area is supported by two potentially-active secondary faults (northeast-trending) that were found in a trench investigation within this zone (AP-3265).

The APEFZ map for the Mt. Wilson quadrangle (CDMG, 1977) shows two additional fault traces, south of the main trace, based on mapping by Proctor (1974b). A trace, west of San Gabriel Blvd., is suggested by a possible south-facing scarp, but an extended trench at San Marino High School failed to find evidence of a fault along this trend. Another strand, near Eaton Wash, was also projected from the east by Crook *et al.* (1987) but there was no evidence for the fault in a trench at Clairbourn School (AP-0397; Crook *et al.*, 1978, trench 5) nor in a trench to the east in the Edison right-of-way (AP-2201). This trace is discussed further with the next fault section.

C. Eaton Wash to Altura Road

The APEFZ map (CDMG, 1977) depicts two subparallel fault traces, based on the map of Proctor (1974b). Crook *et al.* (1987) showed a similar pair of fault traces. The main strand of the Raymond Fault probably lies very close to the northern fault shown by Crook *et al.*, but the previously mapped southern strand does not appear to be supported by more recent evidence and assessment in this study.

The principal strand of the Raymond Fault is fairly well defined by geomorphic features recognized by Buwalda (1940) and Crook *et al.* (1987), and corroborated by our own aerial photo interpretation and limited field observation. North and south-facing scarps as well as drainage deflections adequately define the fault location. Limited fault investigations have not found the fault trace in this area but do serve to limit its location.

The southern fault trace was partly based on a mis-location by Proctor (1974b) of two tilted surfaces originally identified by Buwalda (1940). Scarps and/or vegetation lineaments noted by Crook *et al.* (1987) could not be verified. Numerous fault investigations, per the APEFZ Act (see Plate I), have failed to find evidence of faulting on or near this trace and we believe this fault probably does not exist.

D. Altura Road to Santa Anita Wash

This section of the Raymond Fault appears to be a little more complex than other sections. The complexity has resulted in some of the more dramatic geomorphic expression, with two prominent fault-bounded pressure ridges and a sag area with historic spring activity.

The APEFZ map (CDMG, 1977), Crook *et al.* (1987) and Weaver and Dolan (2000) all depicted a similar pattern of anastomosing fault traces, dominated by the lens-shaped pressure ridge at the Los Angeles Arboretum and the other pressure ridge to the northeast, in Santa Anita Park. Although the western pressure ridge has been consistently depicted as entirely fault bounded, the eastern ridge was not, at least initially. Crook *et al.* and Weaver and Dolan suggested that a fault splay probably controls the north margin of that ridge, as well, albeit with slightly differing locations. Our interpretation generally agrees with the latest mapping at the two pressure ridges, and a trench study confirmed the northern trace at the eastern ridge (Converse Davis, 1973). A detailed geotechnical study of the fault zone at Arcadia Wash (GeoLogic, 2010) did not conclusively define the fault zone but did identify several faults that may represent the merging of the two fault strands from the west.

The area at the northwest end of Santa Anita Park, is more ambiguous than the rest of the zone as it lies in an extensional step between the two pressure ridges. It has usually been characterized as including two fault traces that join together at either end. However, based on constraints from limited subsurface fault investigations we re-interpret the zone as a series of *en echelon* faults within a topographic embayment between the two pressure ridges. A secondary splay, interpreted just to the north, may also control the linearity of the northern slope of that embayment.

The fault has no expression that we could identify in aerial imagery or lidar across the older surfaces of Santa Anita Wash. However, a zone of faults approximately 15 m wide and affecting possible Holocene deposits was identified in one fault investigation (AP-3223), providing some verification of the fault trace in this vicinity. The fault probably continues to the Santa Anita Wash channel on a trend more in line with that shown by Crook *et al.* (1987) rather than the more easterly trend depicted by CDMG (1977). A southern trace across the Santa Anita Wash fan, plotted by CDMG (1977; after Proctor, 1974b), was not found in one fault investigation and we see no evidence for its existence. Aerial photo lineaments further south were also explored by investigation (AP-3452) and no fault was found.

E. Santa Anita Wash to Sawpit Canyon

The current APEFZ fault traces (CDMG, 1977) are probably too far south for most of this fault section, and the fault trace of Crook *et al.* (1987) is probably too simple. Fault investigations at Foothills Middle School (unpublished map by Crook *et al.*, included in AP-1049; Law-Crandall, 1993; Mactec, p.c. 2009) provide some control on the fault location on that campus, but that trace cannot be projected eastward. Instead, we believe the fault likely steps left to create several faceted spurs along the mountain front. That strand continues eastward, with additional facets along the fault trace, and interpretation of lidar data suggests that there may be multiple strands of the fault in this area. Some of these fault strands were corroborated by fault investigations at study locality 16 (EGL, 2001; Slosson, 2003). The fault zone is also interpreted, based on lidar, across young fans emanating from two small canyons near Highland Pl. and Heather Heights Ct., suggesting both location and recency of activity for the fault in this area. Continuing to the northeast, the fault is reasonably placed at the abrupt base of the mountain front until it joins the fault as mapped on the Azusa quadrangle (Treiman, 2013). Fault investigations on the slopes above the fault did not find the main trace but did identify apparent hanging-wall deformation (Petra, 2006; EGL, 2006b, p.c.)

Recommendations

The existing Alquist-Priolo Earthquake Fault Zone for the Raymond Fault on the El Monte and Mt. Wilson quadrangles should be modified, as depicted on Plate III. Largely the changes are related to elimination of some of the southern fault strands that have not been found in fault investigations performed under the Act. A secondary fault trace in the area of the Los Angeles County Arboretum, north of the man trace, is also recommended for zoning.

Some potential faults, north of the main Raymond Fault trace in the San Marino area are ambiguous, do not show evidence of Holocene activity and are not recommended for zoning at this time.

Approved:

4/20/17

5/29/2017

Jerome Treiman

PG 3532, CEG 1035

CERTIFIED ENGINEERING GEOLOGIST
Jerome A. Treiman
No. 1035
STATE OF CALIFORNIA

Tim Dawson

PG 8502, CEG 2618

CERTIFIED ENGINEERING GEOLOGIST
Timothy E. Dawson
No. 2618
STATE OF CALIFORNIA

Table 1

Indirect and direct evidence for faulting as cited by Crook *et al.*, 1978 & 1987
(extracted from Crook *et al*, 1987, Plate 2.4)

INDIRECT EVIDENCE FOR QUATERNARY FAULTING

Locality	Feature
37	Linear depression at Highland Park (Buwalda, 1940, p. 42).
38	Auger boreholes by Glenn Brown in 1973 south of Meridian St. No evidence of offset in alluvium confines buried fault trace between boreholes and toe of scarp.
39	Springs at Arroyo Seco suggest two branches of fault.
40	Coreholes in South Pasadena by California Department of Transportation in 1972; 73 m to diorite south of Raymond fault, but not penetrated in coreholes 107 m deep north of fault (cross section F-F'.
41	Diversion of Alhambra Wash along fault scarp (Buwalda, 1940, p. 46).
42	Possible subsidiary fault parallel to main break (Buwalda, 1940, p. 48). Offset backtilted surfaces suggest fault.
43	Lacy Park depression (sag pond); formerly called Wilson Lake, Kewen Lake, Lake Vineland, and Mission Lake.
44	Depression and pond (Buwalda, 1940, p. 51) and 1929 Fairchild airphotos
45	Pressure ridge.
46	Depression at San Marino High School field (Buwalda, 1940, p. 53).
47	Depression at San Gabriel Boulevard, from old topographic map.
48	Linear cracks in asphalt paving and in concrete wall at Sunny-Slope Reservoir, first noticed in 1973.
49	Left-lateral offset of gully south of nursery.
50	Sharp bend of gulley in Chapman Woods.
51	Depression (Buwalda, 1940, p. 54).
52	Left-lateral offset of gulley.
53	Pressure ridge; "faults converge below" (Buwalda, 1940, p. 55).
54	Scarp and vegetation lineaments on 1929 Fairchild airphoto K-363.
55	Depression at Arboretum (Buwalda, 1940, p. 55).
56	Depression (Buwalda, 1940, p. 56).
57	Diversion of drainage along fault trace.
58	Trenches by Le Roy Crandall & Associates in 1977 for new stables; no evidence of faulting.
59	Pressure ridge (Buwalda, 1940, p. 56).
60	Possible scarp on 1929 Fairchild airphoto K-387 and on 1960 pregrading topographic map of Foothills Junior High School. Trench 1 failed to reveal evidence of fault.

DIRECT EVIDENCE FOR QUATERNARY FAULTING

Locality	Fault feature
58	Scarplets (reported by Buwalda, 1940, p. 43). South of Raymond Hill.
59	Dips of 14° to 58° N. in alluvium. Alhambra Wash, Mill Road, South Pasadena.
60	"4 ft. scarplet" in recent alluvium (Buwalda, 1940, p. 48). Mouth of Kewen Canyon, San Marino.
61	Two definite fault scarps (Buwalda, 1950, p. 51). Huntington Gardens.
62	Fault well exposed in trench 14. San Marino High School.
63	Fault (dip, 56°-80° N.) cutting alluvial and marsh deposits (trench 7). Sunny Slope Reservoir near San Gabriel Boulevard.
64	Alluvial and marsh deposits faulted (dip, 72° N.); exposed in two pipeline trenches. La Presa Drive near Huntington Drive and Sunny Slope Water Co. property.
65	Fault well exposed in trench 15. Edison Co. powerline right of way, north of Huntington Drive, Chapman Woods.
66	Lithologic and color change in trench 6. North side of hill in Arboretum.
67	Recent alluvium faulted against marsh deposits (dip nearly vertical). Trenched in 1973. Baldwin Avenue, Arcadia.
68	Unit 1 or 2 alluvium faulted (dip, 57° N.) Exposure in tract trench, 1973. Intersection of Colorado Place and Colorado Boulevard, Arcadia.

<u>References</u> <u>(consultant studies listed separately)</u>

Bryant, W.A., 1978, The Raymond Hill Fault, an urban geological investigation: California Geology, v.31, no.6, p.127-142.

Bryant, W.A., and Hart, E.W., 2007, Fault-rupture hazard zones in California: California Geological Survey Special Publication 42, 42 p. (digital version only, electronic document available at ftp://ftp.consrv.ca.gov/pub/dmg/pubs/sp/Sp42.pdf).

Buwalda, J.P., 1940, Geology of the Raymond Basin: unpublished report to the City of Pasadena Water Department, 131p.

Byer, J.W., 1975, Sycamore Canyon Fault, Verdugo Fault, York Boulevard Fault, Raymond Fault, and Sierra Madre Fault Zone: Association of Engineering Geologists Field Trip Guidebook, September 27, 1975.

California Division of Mines and Geology, 1977, Special Studies Zones, Mt. Wilson Quadrangle, Official Map, effective January 1, 1977, 1:24,000.

California Division of Mines and Geology, 1991, Special Studies Zones, El Monte Quadrangle, Revised Official Map, effective November 1, 1991, 1:24,000.

California Geological Survey, 2016 (in prep.), Quaternary Fault Database for California, v.3.0.

Crook, R., Jr., Allen, C.R., Kamb, B., Payne, C.M., and Proctor, R.J., 1978, Quaternary geology and seismic hazard of the Sierra Madre and associated faults, western San Gabriel Mountains: USGS, unpublished technical report, Contract No. 14-08-0001-15258.

Crook, R., Jr., Allen, C.R., Kamb, B., Payne, C.M., and Proctor, R.J., 1987, Quaternary geology and seismic hazard of the Sierra Madre and associated faults, western San Gabriel Mountains *in* Recent reverse faulting in the Transverse Ranges, California: U.S. Geological Survey Professional Paper 1339, p. 27-63, plates 1:24,000.

Dolan, J.F., Sieh, K., and Rockwell, T.K., 2000, Late Quaternary activity and seismic potential of the Santa Monica fault system, Los Angeles, California: Geological Society of America Bulletin, v.112, p.1559-1581

Eckis, R., 1934, Geology and ground water storage capacity of valley fill: California Department of Public Works, Division of Water Resources, Bulletin No.45, South Coastal Basin Investigation, 279p., 6 plates. - http://www.unz.org/Pub/EckisRollin-1934

Hauksson, E., Yang, W., and Shearer, P.M., 2012, Waveform relocated earthquake catalog for southern California (1981 to June 2011): Bulletin of the Seismological Society of America, v.102, p.2239-2244.

Hernandez, J.L., 2016, The Hollywood and Raymond Faults in the Los Angeles 7.5’ Quadrangle, Los Angeles County, California: California Geological Survey Fault Evaluation Report FER-260.

Jones, L.M., Sieh, K.E., Hauksson, E. and Hutton, L.K., 1990, The 3 December 1988 Pasadena, California earthquake: evidence for strike-slip motion on the Raymond Fault: Bull. Seismological Society of America, v.80, p.474-482.

Marin, M., Dolan, J.F., Hartleb, R.D., Christofferson, S.A., Tucker, A.Z., and Owen, L.A., 2000, A latest Pleistocene-Holocene slip rate on the Raymond Fault based on 3-D trenching, East Pasadena, California: EOS Trans. AGI, v.81, no.48, Fall Meeting Supplement, Abstract S62B-03.

Miller, W.J., 1928, Geomorphology of the southwestern San Gabriel Mountains of California: University of California, Bulletin of the Department of Geological Sciences, v.17, no.6, p.193-240.

Morton, D.M., 1973, Geology of parts of the Azusa and Mount Wilson quadrangles, San Gabriel Mountains, Los Angeles County, California: California Division of Mines and Geology, Special Report 105, 21p., maps 1:12,000.

Payne, C.M. and Wilson, K.L., 1973, The Sierra Madre Fault System, Field Trip No.3 *in* Association of Engineering Geologists, 1973 Annual Meeting, Field Trips Guidebook.

Payne, C.M. and Wilson, K.L., 1974, Age dating recent movement on the Raymond Fault, Los Angeles County, California: Geological Society of America, Abstracts with Programs, v.6, no.3, p.234-235. [trench near Sunnyslope Reservoir]

Proctor, R.J., 1974a, New localities for fault creep in southern California – Raymond and Casa Loma faults: Geological Society of America, Abstracts with Programs, v.6, no.3, p.238.

Proctor, R.J.,1974b, Preliminary map of geological features along the Raymond Hill fault, scale 1:24,000. [map was reproduced at ~1:48,000 in Byer, 1975].

Treiman, J.A., 1991a, Whittier Fault Zone, Los Angeles and Orange Counties, California: California Geological Survey, Fault Evaluation Report FER-222, 17p., figs., February 1, 1991.

Treiman, J.A., 1991b, Part of the Raymond Fault on the El Monte Quadrangle, Los Angeles County, California: California Division of Mines and Geology, Fault Evaluation Report FER-227, 5p., figs., February 5, 1991.

Treiman, J.A., 2013, The Sierra Madre Fault Zone in the Azusa Quadrangle, Los Angeles County, California: California Geological Survey, Fault Evaluation Report FER-249, 32p., December 20, 2013.

Treiman, J.A., 2014, The Sierra Madre Fault Zone in the Azusa Quadrangle, Los Angeles County, California: California Geological Survey Fault Evaluation Report FER-249, supplement No.1.

USGS, 1928a, Altadena quadrangle – refer to list of topographic maps

USGS, 1928b, Sierra Madre quadrangle – refer to list of topographic maps

Weaver, K.D., and Dolan, J.F., 2000, Paleoseismology and geomorphology of the Raymond Fault, Los Angeles County, California: Bulletin of the Seismological Society of America, v.90, pp1409-1429.

Consultant Studies –

Converse, Davis and Associates, 1973, Foundation investigation review and geologic and Raymond Fault study: unpublished consultant's report, P.N. 73-066-EH, April 3, 1973.

ECI (Earth Consultants International), 2005, Fault investigation for the properties at 879 Michigan Boulevard and 3735 Huntington Drive, in the Pasadena area, Los Angeles County, California: PN.2430.01, February 9, 2005.

EGL is Environmental Geotechnology Laboratory Inc.,

EGL 1999, Engineering geologic investigation and response to comments of LA County building plan check no.9905100026, proposed new house, 820 S. Woodward Blvd., Pasadena, California: PN.99-114-006, November 1, 1999.

EGL, 2001, Report of geotechnical engineering investigation and fault trace evaluation, proposed residential development, El Nido, Monrovia, California: PN.01-241-002GE, September 14, 2001.

EGL, 2002, Fault trace evaluation, proposed new 23 units condominiums, 879 Michigan Boulevard & 3735 Huntington Drive, County of Los Angeles, California: PN 02-177-003F, August 15, 2002.

EGL, 2003, Addendum fault trace evaluation, proposed new building development, El Nido, Monrovia, California: PN.01-241-002F, October 22, 2003.

EGL, 2006a, Engineering geologic and geotechnical report and seismic fault investigation, proposed house addition at lot 2 and northerly 2.75' portion of lot 1, tract licensed surveyors, 731 Michillinda Avenue, Pasadena, Los Angeles County, California: PN 06-203-010EG, July 25, 2006.

EGL, 2006b, field logs and notes only for fault investigation at 428 N. Alta Vista Avenue, Monrovia, CA

EGL, 2011, Report of engineering geologic and geotechnical engineering investigation, proposed single-family residence, lot 14, block A, tract no.10884, 3340 Martha Circle, Pasadena, California: PN.11-234-003GE, November 7, 2011.

EGL, 2015, Report of engineering geologic and geotechnical engineering investigation and updated seismic fault investigation, proposed single-family residence, lot 24, block B, Michillinda tract, 838 Michigan Boulevard, Pasadena, California: PN.15-037-002EG, October 21, 2015.

EGL, 2016a, Report of geotechnical engineering investigation, proposed new single-family residence at 856 Vallombrosa Drive, Pasadena, California: PN.15-128-009L, July 28, 2016.

EGL, 2016b, Engineering geologic and seismic fault investigation report, proposed residential development at lot 3 of Michillinda tract, 3839 E. California Boulevard, Pasadena, Los Angeles County, California: PN 16-257-003EG, August 23, 2016.

GeoLogic, 2010a, Fault study for iconic structure, Metro Gold Line – proposed Foothill Extension, Arcadia, California: JN. 2009-0095, February 26, 2010.

GeoLogic, 2010b, GeoLogic Associates Design Addendum No.1, response to Caltrans memorandum dated March 25, 2010, fault study report review – Raymond Fault: PN.2010-025, April 2, 2010.

Law/Crandall, 1993, Report of fault rupture hazard investigation, Foothill Junior High School, 171 East Sycamore Avenue, Arcadia, California, for Arcadia Unified School District: JN 2663.30841.0001, December 15, 1993.

LeRoy Crandall and Associates, 1977, (?, title not available – fault investigation at San Marino H.S.): project no. E77186, logs and maps dated 9-13-77 provided by R. Crook (p.c.)

LeRoy Crandall and Associates, 1990, Report of fault rupture hazard investigation, Hugo Reid Elementary School, Arcadia, California, for the Arcadia Unified School District: unpublished consultant's report LCA L89436.EB, July 24, 1990.

Leighton-Yen and Assoc., 1973, Geotechnical analysis of Huntington Oaks Townhouses, San Marino area, California: unpublished consultant report PN.73220-1, October 9, 1973.

MACTEC, 2009, Foothill Middle School, location map and limited subsurface data from uncompleted investigation for Arcadia Unified School District (Foothill MS): PN.4953-07-1581, undated but relayed to CGS in 2009.

Petra, 2006, Fault-rupture hazard study, proposed single-family residential development, AIN 8520-024-023, Alta Vista Avenue, City of Monrovia, California: JN.254-06, May 10, 2006.

Quartech Consultants, 2013, Fault investigation and evaluation report, proposed single family residence at 3901 E. California Boulevard, APN 5378-025-001, Pasadena, California: QCI PN.13-205-001GE, June 26, 2013.

Quartech Consultants, 2015, Response to County of Los Angeles geologic and soils engineering review sheet dated September 29, 2014, proposed residential development, 3901 E. California: QCI PN.13-205-001GER, January 26, 2015.

RMA Group, 1994, Geotechnical investigation for the proposed Van Nuys Reservoir, Huntington Drive, west of N. Gainsborough Dr., San Marino, CA: Job No.94-025-01, dated April 19, 1994, 13p. [report not available but cited by Wilson Geoscience, 1996].

Slosson and Associates, 2003, Engineering geology review of reports prepared for the proposed residence at 314 El Nido Avenue: PN.0031007, September 2, 2003.

Slosson and Associates, 2004a, Engineering geology review of "Addendum fault trace evaluation, proposed new building development, El Nido, Monrovia, California, EGL Project No.01-241-002F" prepared by Environmental Geotechnology Laboratory, Inc, dated October 22, 2003: PN.031007, October 12, 2004.

Slosson and Associates, 2004b, Engineering geology review of "Fault rupture hazard evaluation for the property located at 314 El Nido Avenue, in the city of Monrovia, Los Angeles County, California" prepared by Earth Consultants International, dated July 15, 2004: PN.031007, October 27, 2004.

Stone, A., 2014, Fault investigation, 838 Michigan Blvd., Pasadena, California: PN.14-17-00, May 19, 2014.

Wilson Geosciences, 1996, Limited geologic evaluation and fault investigation in support of an environmental impact report for the San Gabriel County Water District projects: Longden Reservoir, Van Nuys Reservoir, Longden booster pump station and the 24-inch parallel water pipeline: January 9, 1996, 24p.

The following numbered consultant studies have been submitted to the CGS under provisions of the Alquist-Priolo Earthquake Fault Zoning Act and are listed by their A-P file numbers.

AP-0397 --

Leighton and Associates, 1977, Geologic and soil engineering investigation of the Clairbourn School, San Gabriel area, county of Los Angeles: Project No. 77017-1, dated February 11, 1977.

Leighton and Associates, 2000, Preliminary geotechnical investigation, proposed new classroom building, Clairbourn school, 8400 Huntington Drive, in the San Gabriel area of unincorporated Los Angeles county, California: Project No. 020089-001, dated May 10, 2000.

AP-0461 --

LeRoy Crandall and Associates, 1977, Report of geologic-seismic and fault rupture investigation proposed horse barns, Santa Anita Park, Arcadia, California for the Los Angeles Turf Club, Inc.: File no E-77124, dated May 18, 1977.

AP-0830 –

GeoSoils, Inc., 1978, Seismicity study northeast corner of Foothill Boulevard and Santa Anita Avenue, City of Arcadia, California: W.O. 565-OC, dated September 14, 1978.

AP-1032 –

LeRoy Crandall and Associates, 1979, Report of geotechnical investigation, proposed classroom addition, 226 West Colorado Boulevard, Arcadia, California for Santa Anita Church/Barnhart School: Job No. AE-79262, dated September 20, 1979.

AP-1049 --

Soils International, 1979, Geologic and seismic and refraction investigation, proposed residential development, Blade Construction Co., N.E.C. Sycamore and Oakglen Avenues, Arcadia, California: File No. L-1038-GE, dated October 5, 1979.

AP-1149 --

Kovacs-Byer and Associates Inc., 1980, Foundation and site seismicity investigation, proposed medical offices, 41 West Foothill Boulevard, Arcadia, California: File No. KB 5397-G, dated January 21, 1980.

AP-1226 --

Bob Dickey Geotechnical Incorporated, 1980, Geologic and fault study of proposed residential site tentative parcel map no. 12913, 1040 San Gabriel Blvd., County of Los Angeles, California: Duco job 0-176, dated September 17, 1980.

AP-1428 --

California Geo Systems Inc., 1982, Preliminary geologic seismic investigation report for proposed parcel map no. 14975, 855 Chapea Road, Arcadia area of the county of Los Angeles, California: File no. GS82-210, dated February 18, 1982.

AP-1455 --

LeRoy Crandall and Associates, 1982, Report of fault rupture investigation Raymond fault, proposed horse barn additions, Santa Anita Park, Arcadia, California: Job No. E-82112, dated May 14, 1982.

AP-1525 --

LeRoy Crandall and Associates, 1983, Report of geotechnical investigation, proposed bookstore, 226 West Colorado Boulevard, Arcadia, California: Job No. AE-83006, dated January 27, 1983.

AP-1616 --

Kovacs-Byer and Associates Inc., 1983, Foundation and site seismicity investigation, proposed three story offices, portion of lot 3, CB Clapps subdivision, 50 East Foothill Boulevard, Arcadia, California: File No. KB 7634-G, dated August 17, 1983.

AP-1689 --

Foundation Engineering Co., Inc., 1984, Geotechnical report for proposed Arcadia retirement hotel, 730 Michillinda Avenue, Arcadia, California: Tract No. 14846, dated April 9, 1984.

AP-1761 --
Soils International, 1984, Proposed office building development, 301 to 317 Foothill Boulevard, Arcadia, California, Addendum No. 1 to report of September, 1983: Project No. L-1609-F, dated December 18, 1984.
AP-1815 --
Hershel Gene Hawkins, 1985, Geologic report tentative tract no. 43726, 8814 Huntington Drive, San Gabriel, California: dated June, 25 1985.
AP-1837 --
Atlantis Scientific, 1979, Environmental impact report, tentative tract no. 36843, Monrovia, California: dated May 25, 1979.
AP-1838 --
Earth Research Associates Inc., 1978, Preliminary soils engineering investigation, tentative tract no. 33842, City of Monrovia, California: Job No. 373-77, dated March 15, 1978.
Earl R. Morley, Jr., 1978, Preliminary engineering geologic report for tentative tract no. 33842, City of Monrovia, California: Project No. 690-97, dated March 20, 1978.
AP-1896 --
Triad Foundation Engineering Inc., 1986, Preliminary soils and geologic investigation, proposed school building, 226 W. Colorado Boulevard, Arcadia, California: Job No. 86-17, dated February 6, 1986.
AP-1972 --
Richard Crook, Jr., 1986, subsurface fault investigation on lots 13 and 17, E. Foothill Blvd., Arcadia, California: dated June 11, 1986.
AP-2018 --
Hu Associates, 1987, Preliminary soil investigation, proposed condominium complex, 1231 North Lotus Avenue, San Gabriel, California: Project No. HA-2309-3, dated May 7, 1987.
AP-2197 --
Smith-Emery Company, 1988, Geotechnical investigation addendum no. , Ralphs grocery company #41, proposed store addition, 211 East Foothill Boulevard, Arcadia, California: File No. 80159, dated August 12, 1988.
AP-2201 --
Richard Crook, Jr., 1988, Subsurface fault investigation at Sunnyslope Gardens, tentative tract no. 46605, Muscatel Avenue, Los Angeles County, California: dated October 24, 1988.
AP-2256 --
California Geo Systems Inc., 1989, Addendum to soils engineering and geologic seismic investigation report for proposed retail stores and parking area, lot 2, P.M. 1366, Northeast corner of Santa Anita and Floral Avenue, Arcadia, California: File No. GS89-104-1, dated April 5, 1989.
AP-2706 --
Richard J. Proctor, Inc., 1993, Alquist-Priolo investigation for the Raymond fault, proposed lot split at this address, tentative minor land division no. 23866, unincorporated part of Los Angeles, 3029 N. Gainsborough Drive, Pasadena, California: dated August 31, 1993.
AP-3058 --
Ray A. Eastman, 1997, Fault line investigation site of proposed residential development, 8800 Huntington drive, Arcadia, California: Project No. 1669, dated February 10, 1997.

AP-3206 --
Terra Geosciences, 2002, Geologic fault investigation, Huntington project, 3.7 acres, 3303 Huntington Drive, Pasadena, California: Project No. 221474-1, dated April 3, 2002.
AP-3218 --
MTC Engineering, Inc., Preliminary geotechnical engineering investigation fault study, and seismic risk assessment report, proposed one-story building addition, 3139 Piccolo Street, Pasadena, California: Project No. 495-1-1SF&S, dated April 24, 2002.
AP-3223 --
Secor International Incorporated, 2002, Fault investigation report, rebuild of ARCO facility no. 1592, 5 W. Foothill Boulevard, Arcadia, California: Project no. 004.65246.00.0002, dated September 17, 2002.
Secor International Incorporated, 2002, Geotechnical investigation, rebuild of ARCO facility no. 1592, 5 W. Foothill Boulevard, Arcadia, California: Job No. 04BP.65246.00.0002, dated July 25, 2002.
AP-3233 --
Earth Consultants International, 2002, Fault rupture hazard evaluation for the property located at 829 Madre Street, in the Chapman Hills area of Los Angeles County, southeast of Pasadena, California: Project No.2119.01, dated November 5, 2002.
AP-3241 --
Kleinfelder, 2000, Report of geologic fault investigation proposed sunrise assisted living facility, 8332 Huntington Drive, San Gabriel, California: dated May 25, 2000.
AP-3265 --
MTC Engineering Inc., Preliminary geotechnical engineering investigation fault study, and seismic risk assessment report, proposed subdivision with proposed one-story residential building on the new lot and building addition to the existing building, 3029 Gainsborough Drive, Pasadena, California: Project No. 608-1-1SF, dated June 13, 2003.
AP-3384 --
Sladden Engineering, 2006, Geologic fault investigation, proposed commercial complex, 8984 Huntington Drive, San Gabriel area, Los Angeles County, California: Project No. 466-5173, dated August 2, 2006.
AP-3452 --
Construction Testing and Engineering, 2011, Fault hazard investigation proposed supervisor’s building, Angeles National Forest, Arcadia, California: Job No. 30-0933G, April 15, 2011.
AP-3454 --
Environmental Geotechnology Laboratory Inc., Engineering geologic and seismic fault investigation report, proposed residence at lot 10, tract no. 13756, 3051 Stoneley Drive, Pasadena, County of Los Angeles, California: Project No. 10-114-011EG, dated May 26, 2011.

AERIAL PHOTOS USED

Fairchild Aerial Surveys

1928 Flight C-300	*black/white*	*7"x9"*	*scale 1:20,000*	
frames K293-295, K316-319, K336-340, K362-364, K386-389, L8-10				

U.S. Department of Agriculture

1938		*black/white*	*7.5"x9.5"*	*scale 1:20,000*
	AXJ-44	frames 13-19, 48-52		6/5/38
	AXJ-68	frames 91-94, 96-97		7/15/38
1952-1954		*black/white*	*9"x9"*	*scale 1:20,000*
	AXJ-5K	frames 33-35		11/10/52
	AXJ-13K	frames 161-163, 174-176		10/19/53
	AXJ-19K	frames 66-68		10/26/54

TOPOGRAPHIC MAPS -- all published by U.S. Geological Survey

Altadena Quadrangle
1928 6-minute series (1:24,000) for Los Angeles County (1924 survey data)

El Monte Quadrangle
1966 7.5-minute series (1:24,000) (photorevised 1981)

Mt. Wilson Quadrangle
1966 7.5-minute series (1:24,000) (photorevised 1988)

Sierra Madre Quadrangle
1928 6-minute series (1:24,000) for Los Angeles County (1925 survey data)
1941 6-minute series (1:24,000) for Los Angeles County (1925 & 1933 survey data)

DIGITAL ELEVATION DATA

LARIAC (Los Angeles Region Imagery Acquisition Consortium): proprietary dataset, lidar data acquired 2006. (1.7 m DEM) http://planning.lacounty.gov/lariac

USGS-MHDP (U.S. Geological Survey, Multi-Hazards Demonstration Project), San Gabriel Lidar Survey: data acquired June 2009. (0.5 m DEM)